

REMARKS

Applicants thank the Examiner for the thorough consideration given the present application. Claims 4-21 and 26-28 are currently under consideration. Claims 22-25 have been withdrawn from consideration. Claims 1-3 have been cancelled and replaced by new claims 26-28. The Examiner is respectfully requested to reconsider his rejections in view of the amendments and remarks as set forth below.

Drawing

The Examiner objected to the drawings filed on August 30, 2001. The objection is apparently located in the PTO-948 Drawing Review Sheet which indicates that the left margin of Figure 2 is improper. Applicants are resubmitting a proper copy of this drawing to correct this problem.

Restriction

The Examiner required a restriction between three inventions. As indicated by the Examiner, a provisional election was made to prosecute invention I including claims 1-21. Applicants hereby affirm this election which was previously made by telephone.

Rejection Under 35 U.S.C. § 112

The claims were rejected under 35 U.S.C. § 112, second paragraph as being indefinite due to various language problems. These rejections are respectfully traversed.

First, the Examiner rejected claims 1-21 due the use of "predetermined" in regard to the purge times. By way of the present Amendment, this language has been removed rendering this rejection moot.

Claims 1 and 2 were rejected as being indefinite due to the description of the supplying of the raw materials. This language has now been reworded to avoid these problems.

Claims 1-3 were rejected due to the use of the word "maintaining" in regard to the purge times. By way of the present Amendment, this language has been removed, so that this rejection is also overcome.

Claim Objections

The Examiner objected to claim 21 due to a lack of the full chemical name. By way of the present Amendment, these have been added before the first occurrence of each abbreviation so that this objection is now overcome.

Rejection Under 35 U.S.C. § 102

Claims 1, 2, 3, 6, 7, 11, 12, 16 and 17 stand rejected under 35 U.S.C. § 102 as being anticipated by Nishizawa et al. (U.S. Patent No. 5,693,139). This rejection is respectfully traversed.

Applicants submit that the Nishizawa et al. reference does not disclose all of the features of the present claimed invention. The Examiner points out that the Nishizawa et al. reference shows a method of growing doped semiconductor monolayers having raw material gases of gallium and arsenic and where the chamber is evacuated between

applications of the gases. In addition, the reference shows the forming of a p-type layer by introducing an impurity gas. Alternatively, an n-type layer can be formed with a different type of impurity gas.

Claims 21 and 26-28 describe a method of impurity doping having a combination of steps, including one cycle having the supplying of crystal raw materials separately with purge times being inserted between the supplying of the crystal raw materials. Also, impurity raw materials are supplied, each for a given time with these given times being close together. The result of this is the forming of impurity pairs in the crystal layer. Applicants submit that the reference does not include this combination of steps. In particular, it does not disclose the supplying of more than one impurity raw material within a cycle and the formation of impurity pairs thereby.

The concept of the impurity pairs is based on a theory known as "co-doping" which has been suggested by Professor Yoshida of Osaka University. The present invention is based on this theory and provides a method for realizing the theory. Usually, when a band gap becomes wide, the energy level becomes deep and the carriers of holes do not appear in the charged band if only an acceptor is formed in the crystal. Thus, a p-type semiconductor is not formed. However, the co-doping theory teaches that when a complex of acceptor and donor (acceptor-donor complex) is formed in a crystal, a shallow acceptor level is created due to the binding energy of the donor and acceptor, as has been theorized by Professor Yoshida.

In view of this theory, people have tried to form an acceptor-donor complex in a crystal by simultaneously introducing acceptor and donor impurities during crystal growth and have tried to create material having high acceptor concentration or having low

activation energy, but this has not been successful. This is at least partially because the donor and acceptor cannot easily move in the crystal and therefore there is little possibility that they may move around and create a complex. Figure A which is attached indicates how the donor and acceptor impurities are spread throughout the crystal lattice.

The present inventors have realized that atoms move very easily on a crystal surface and as a result have accomplished the subject invention. The donor and acceptor are introduced onto one of the atomic layers of a crystal raw material. Alternatively, one of the donor and acceptor is introduced into one layer and the other is introduced onto the next layer of the same material. The donor and acceptor are supplied either at the same time of the starting of the crystal raw material or after the supply thereof and before starting the supply of the other crystal raw material. As a result, the donor atoms and the acceptor atoms freely move and associate with each other in order to form acceptor-donor complexes, as shown in attached Figure B.

The results described are shown in Figure C which show the effect of the subject invention which indicates that the acceptor-donor complexes were created. The subject invention has succeeded in realizing hole concentrations of $1 \times 10^{19}/\text{cm}^3$ and hole concentration of $5 \times 10^{18}/\text{cm}^3$ in AlGaIn which has previously not been possible.

This situation is completely different from the doping method shown by Nishizawa et al. In that arrangement, the compound semiconductor becomes p-type when the acceptor is introduced into an atomic layer with certain timing and becomes n-type when the donor is introduced into another atomic layer. This is not at all part of the co-doping theory and uses a different type of atom as an impurity. As a result, it is still impossible in such an

arrangement to obtain a high concentration hole in material such as GaAlN having a wideband gap.

In particular, since the reference does not show the concept of having plural impurity raw materials supplied in a crystal layer and having impurity pairs formed thereby, Applicants submit that the reference does not teach the limitations provided in claims 21 and 26-28. Accordingly, these claims are considered to be allowable.

Claims 4-20 depend from claims 26-28 and as such are also considered to be allowable. In addition, each of these claims recites additional features which taken in conjunction with the allowable features of claims 26-28 are also considered to be allowable. Thus, these claims further indicate the timing of the supplying of the impurity raw materials, the particular grouping of materials supplied for the crystal raw material and the use of p-type and n-type impurity raw material. Accordingly, these claims are considered to be additionally allowable.

Rejection Under 35 U.S.C. § 103

Claims 1-21 stand rejected under 35 U.S.C. § 103 as being obvious over Nishizawa et al. in view of Edmond et al. (U.S. Patent No. 5,739,554). Claim 21 also stands rejected as being obvious over Nishizawa et al. in view of Edmond et al. and further in view of Manabe et al. (U.S. Patent No. 6,472,690). These rejections are respectfully traversed.

The Examiner relies on the Edmond et al. reference to teach a gallium nitride layer doped with both a group II acceptor and group IV donor. However, even if this reference does teach the concept of having two such impurities, it does not teach the concept of the

impurity pairs as discussed above and as presently claimed. Accordingly, Applicants submit that the claims are allowable even over this combination of references.

The Examiner cited the Manabe et al. reference to show the use of TESI material. Applicants submit that even if this reference does teach such a use, that the claims would still be allowable over this three way combination. Such a combination of references still does not teach the claimed invention and in particular, the use of the impurity pair.

CONCLUSION

In view of the above remarks, it is believed that the claims clearly distinguish over the patents relied on by the Examiner, either alone or in combination. In view of this, reconsideration of the rejections and allowance of all the claims are respectfully requested.

Should there be any outstanding matters that need to be resolved in the present application, the Examiner is respectfully requested to contact Robert F. Gnuse (Reg. No. 27,295) at the telephone number of the undersigned below, to conduct an interview in an effort to expedite prosecution in connection with the present application.

Pursuant to 37 C.F.R. §§ 1.17 and 1.136(a), Applicants respectfully petition for a one (1) month extension of time for filing a response in connection with the present application and the required fee of \$110.00 is being filed concurrently herewith.

Attached hereto is a marked-up version of the changes made to the application by this Amendment.

If necessary, the Commissioner is hereby authorized in this, concurrent, and future replies, to charge payment or credit any overpayment to Deposit Account No. 02-2448 for any additional fees required under 37 C.F.R. §§ 1.16 or 1.17; particularly, extension of time fees.

Respectfully submitted,

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1794-0141P

Attachment: Version with Markings to Show Changes Made

(Rev. 02/20/02)

VERSION WITH MARKINGS TO SHOW CHANGES MADE

IN THE CLAIMS:

Please cancel claims 1-3 without prejudice or disclaimer of the subject matter contained therein.

Please amend claims 4-8, 11-13 and 21 as follows:

4. (Amended) An impurity doping method for semiconductor as claimed in claim [3] 28 wherein:

a supply of said first impurity raw material is started in synchronous with starting a supply of said first crystal raw material, a supply of said second impurity raw material is started after finishing the supply of said first impurity raw material, and the supply of said second impurity raw material is finished before starting the supply of said second crystal raw material.

5. (Amended) An impurity doping method for semiconductor as claimed in claim [3] 28 wherein:

there is a period of time wherein said first impurity raw material is supplied with said second impurity raw material at the same time.

6. (Amended) An impurity doping method for semiconductor as claimed in claim [1] 26 wherein:

a crystal raw material supplied precedently within said one cycle in said crystal raw materials is at least one member selected from the group consisting of Ga, Al, In, B, Zn,

and Cd, while a crystal raw material is supplied latterly within said one cycle is at least one member selected from the group consisting of N, As, P, S, Se, and Te.

7. (Amended) An impurity doping method for semiconductor as claimed in claim [2] 27 wherein:

a crystal raw material supplied precedently within said one cycle in said crystal raw materials is at least one member selected from the group consisting of Ga, Al, In, B, Zn, and Cd, while a crystal raw material supplied latterly within said one cycle is at least one member selected from the group consisting of N, As, P, S, Se and Te.

8. (Amended) An impurity doping method for semiconductor as claimed in claim [3] 28, wherein:

a crystal raw material supplied precedently within said one cycle in said crystal raw materials is at least one member selected from the group consisting of Ga, Al, In, B, Zn and Cd, while a crystal raw material supplied latterly within said one cycle is at least one member selected from the group consisting of N, As, P, S, Se and Te.

11. (Amended) An impurity doping method for semiconductor as claimed in claim [1] 26, wherein:

said impurity raw materials are a p-type impurity raw material and an n-type impurity raw material.

12. (Amended) An impurity doping method for semiconductor as claimed in claim [2] 27, wherein:

said impurity raw materials are a p-type impurity raw material and an n-type impurity raw material.

13. (Amended) An impurity doping method for semiconductor as claimed in claim [3] 28, wherein:

said impurity raw materials are a p-type impurity raw material and an n-type impurity raw material.

21. (Amended) An impurity doping method for semiconductor wherein a crystal layer made of crystal raw materials is doped with impurities, comprising:

a cycle composed of:

a first step wherein a supply of trimethylgallium (TMGa) [TMGa] and biscyclopentadienyl magnesium ((Cp)₂Mg) [(Cp)₂Mg] is started at a first timing, and the supply of TMGa and (Cp)₂Mg is finished at a second timing at which the supply TMGa and (Cp)₂Mg for a predetermined period of time was completed;

a second step wherein a supply of tetraethylsilane (TESi) [TESi] is started either immediately after, or after the second timing at which the supply of TMGa and (Cp)₂Mg was finished, and the supply of TESI is finished at a third timing at which the supply of TESI for a predetermined period of time was completed;

a third step wherein a supply of ammonia (NH₃) [NH₃] is started either immediately after, or after the third timing at which the supply of TESI is finished, and the supply of NH₃

is finished at a fourth timing at which the supply of NH_3 for a predetermined period of time was completed; and

a fourth step wherein a [predetermined] purge time is started after the supply of NH_3 is finished at the fourth timing at which the supply of NH_3 was completed, and said [predetermined] purge time is finished at a fifth timing;

wherein an impurity pair is formed in said crystal layer;

said first through fourth steps being repeated a desired number of times.

New claims 26-28 have been added.